Effect of Partial Grapevine Defoliation (*Vitis vinifera*) on Wine Quality

Efecto de la Defoliación Parcial en Uva (*Vitis vinifera*) sobre la Calidad del Vino

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Abstract. The wine quality was determined for partially-defoliated grapevines grown in Villa de Leyva, Colombia at an elevation of 2,143 masl. The experimental design was totally randomized, with two treatments (50% defoliation and 0% defoliation) and three repetitions per treatment. The planting material consisted of five-year-old vines of **Vitis vinifera** cv. Chardonnay, trained to trellises, with a spacing of 2.1 m x 1 m. Every fifteen days, the plants in the defoliation treatment underwent the removal of half of the newly-emerged leaves. Before undertaking the micro-vinification process, the total soluble solids (TSS) were measured in the grape must, and after a fermentation of 100 days, wine quality parameters were measured, namely: residual sugars (TSS of the wine), pH, total titratable acid (TTA), and potential alcohol content of the wine. In the plants undergoing partial defoliation, the total soluble solids in the grape must increased, as well as the wine pH and potential alcohol content. At the same time, total titratable acid decreased in the wine of partially-defoliated plants. These results demonstrate that the wine quality was greatly improved by the reduction of leaf area in Chardonnay variety grape plants.

Key words: Ecophysiology, quality characteristics, abiotic factors, maturity index.

Resumen. Con el uso de un diseño completamente aleatorizado, con dos tratamientos (defoliación al 50% y sin defoliación parcial) y tres repeticiones por tratamiento, se determinó la calidad del vino en plantas de uva sometidas a defoliación parcial temprana en Villa de Leyva – Colombia a una altitud de 2.143 msnm. Como material vegetal se utilizaron plantas de **Vitis vinifera** L. cv. Chardonnay de cinco años de edad, sembradas en un sistema de espalderas a 2,1 x 1 m. Quincenalmente, se realizó la defoliación parcial a las plantas, la cual consistió en retirar una de cada dos hojas recién emergidas en cada una de las plantas sometidas al tratamiento de defoliación. Antes de iniciar el proceso de micro-vinificación se determinaron los sólidos solubles totales (SST) del mosto, y posterior a la fermentación alcohólica, la cual tuvo una duración de 100 d, se determinaron los parámetros de calidad del vino, como: azucares residuales (SST del vino), pH, acidez total titulable (ATT) y contenido potencial de alcohol del vino. Se encontró un aumento en los SST del mosto, el pH y el contenido potencial de alcohol del vino procedente de las plantas defoliadas. A su vez, la ATT del mismo disminuyó en las plantas defoliadas. Estos resultados demuestran que la calidad del vino se vio favorecida fuertemente por la disminución del área foliar en plantas de uva cv. Chardonnay.

Palabras clave: Ecofisiología, características de calidad, factores abióticos, índice de madurez.

The history of grape-growing in Colombia is principally linked to the production of table grapes for fresh consumption, as opposed to wine production. Large expanses of table grape plantations are found in a few departments of the country, chiefly Valle del Cauca (Almanza-Merchán *et al*., 2012). Nevertheless, many differences exist between this production system and wine-growing, the latter of which occurs mainly in Boyacá (Camacho, 2007). Grapes from wine varieties are juicy and produce sweet, semi-sweet, and dry wine, any of which can be white, red, or rosé (Almanza, 2012; Almanza *et al*., 2012). There is little research in Colombia regarding new growing practices to improve grape and wine quality; this lack of research and innovation discourages winegrowers from expanding cultivated areas and thus national wine production. It is therefore necessary to look for agronomic strategies that can improve fruit quality, which will in turn raise standards for Colombian wine.

While Colombian wine possesses decent quality characteristics, quality is not optimal and can be improved. Artificial defoliation in grapevines is often an effective way of improving fruit quality; since plants increase total soluble solids and phenolic compounds when subjected to stress (defoliation, for example), and these substances are key to the production of high-quality wine (Intrieri *et al*., 2008).

To obtain quality wine, it is important to know the physical and chemical characteristics of the grape at the moment of maturity. Sugar content (total soluble

solids) determines the probable alcohol content for each type of wine, and as such, is the most practical parameter for winegrowers to look at (Almanza, 2012). The brightness, freshness, aroma, and the appearance of microorganisms that directly affect quality of wine all depend on fruit acidity at harvest. Low concentrations of anthocyanins lead to a lack of color in wine (Rodríguez *et al*., 2010). Almanza *et al*. (2011) indicated that the maturity index represents a balance between sugars and acids, which is important for wine because it lends to a balanced flavor.

Grapes contain many chemical compounds in addition to the sugars that act as a precursor for wine fermentation (Quijano, 2003). A programmed reduction in leaf area is an efficient way of reducing yield and improving grape quality (Intrieri *et al*., 2008; Hunter *et al*., 1991). Good wine is a result of good grape quality, which in turn is the result of a series of factors such as variety, environment, climate, and growing practices. These factors interact to determine the optimum content of sugars and aromatic compounds that form during fruit ripening (Almanza *et al*., 2010; Rodríguez *et al*., 2010).

The present study aimed to evaluate the influence of early partial defoliation on wine quality in Chardonnay plants, under cool highland tropical conditions.

MATERIALS AND METHODS

The experiment was undertaken at the Guananí vineyard in Villa de Leyva, Colombia (5°38' N, 73°32' W) at an altitude of 2,143 masl, with an average temperature of 16.9 °C and an average annual precipitation of 716.9 mm. A completely randomized design was used, with two treatments
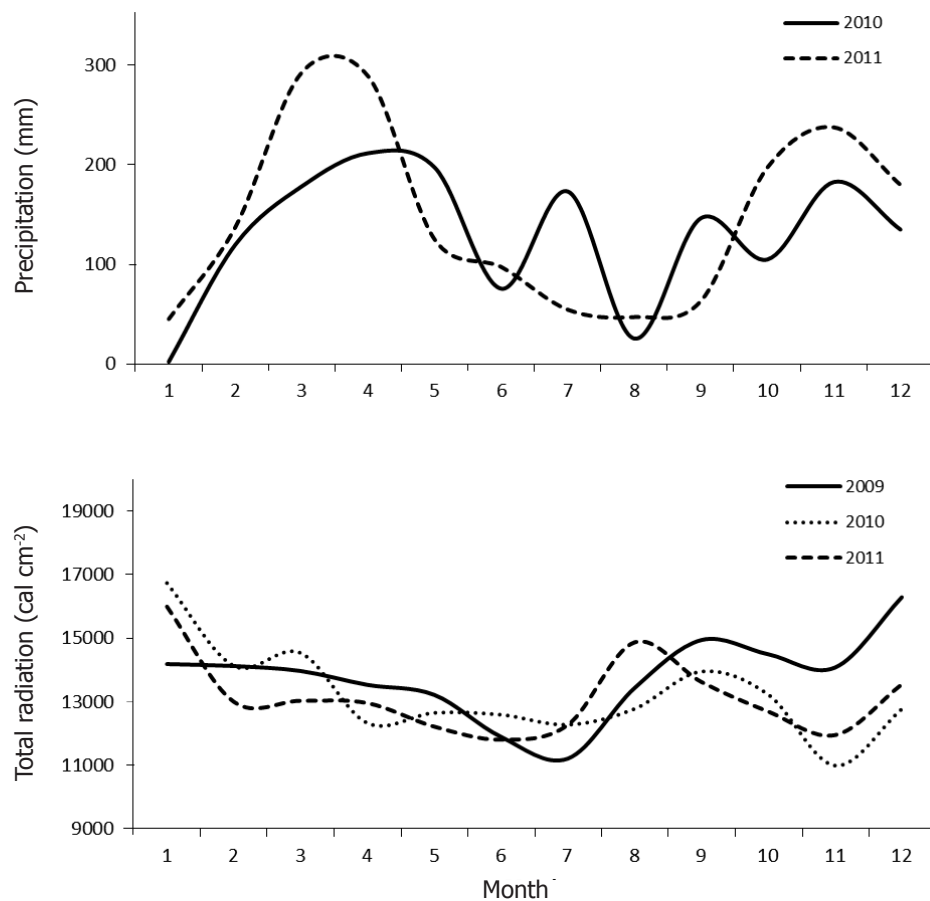

Figure 1. Total radiation (2009-2011) and precipitation (2010 and 2011) in the study area (Duitama- Colombia).

(50% defoliation and a non-defoliated control) and three replications per treatment. The plants were 5-year-old grapevines of the Chardonnay variety, planted in a trellis system at a density of 2.1 m x 1 m. From the moment of initial induction pruning until 121 days afterwards (in tropical growing conditions with no marked alternation between cold and warm seasons, it is necessary to severely prune grapevines to induce the start of the production cycle; this is common practice in Boyacá, Colombia), partial defoliation was performed every 15 days. This consisted of removing half of the newly emerged leaves on each of the grapevines under the defoliation treatment. Climatic trends for the study area were obtained from the IDEAM weather station located in Duitama, Boyacá, Colombia (Figure 1).

The grapes were harvested 130 days after the initial induction pruning and crushed to obtain must, and the total soluble solids (TSS) were determined by refractometry. The micro-winemaking process consisted of fermentation in plastic bottles, fitted with air traps to prevent entry of oxygen while allowing evacuation of CO_2. This process lasted 100 days. To analyze the wine quality, the following measurements were taken: percentage of residual sugars (TSS of the wine) using an ATC/FG-711 portable refractometer (Zhifong®, Changhua, Taiwan); pH using a waterproof pHep potentiometer (Hanna® Instruments, Carollton, USA); titratable acidity using the methodology described by Diaz *et al*. (2008); and potential alcohol content by refractometry using the formula: potential alcohol content (% v/v) = (0.6757 ∗ °Brix) − 2.0839. The Brix value in the latter formula was taken as the difference between must TSS and wine TSS (also known as residual sugars), in order to give a more exact figure for potential alcohol content in the wine produced.

Fleischmann® brand brewing yeast (*Saccharomyces cereviceae*) was used for the winemaking process (Fleischmann, 2007) at a rate of 20 g per 100 L wine, according to the standard practice in the Guananí vineyard.

The data were subjected to a classical variance analysis (P<0.05) using the PASW (Predictive Analytic Software) program, version 18.0.0 (30 July 2009; IBM® Corporation, Somers, USA).

RESULTS AND DISCUSSION

The total soluble solids in the three-month-old ("young") wine showed no significant difference between treatments, although the TSS in the must did give significantly different values (P<0.05). The must obtained from the defoliated plants showed an 8.08% increase in this variable as compared to the must from the control plants. With respect to potential alcohol content (% v/v) in the wines, significant differences were also found; the potential alcohol percentage increased 9.62% in wines from the defoliated plants, as compared to wine from the control plants (Table 1).

Table 1. Quality characteristics in wines produced from partially defoliated grape plants, *Vitis vinifera* L. cv. Chardonnay (n=3).

Treatment	TSS must (°Brix)	Residual sugars (TSS of wine)	Potential alcohol (% v/v)*
Defoliation 50%	19.53± 0.12 a	1.27 ± 0.12 a	10.25 ± 0.81 a
Control	18.07± 0.12 b	1.13 ± 0.12 a	9.35 ± 0.75 b

* Potential alcohol was derived by applying the formula %vol = (0.6757 ∗ °Brix) − 2.0839, with Brix taken as the difference between must TSS and wine residual sugars.
Different letters indicate significant differences (P<0.05) according to variance analysis.

The quantity of the residual sugars classifies this as a medium dry wine, defined as having values between 4 and 12 g L^{-1} (Junta de Andalucia, 2011). Nevertheless, it is surprising that there are more residual sugars in the wine from the defoliated plants. It is possible that defoliation, by inducing a strong flow of photoassimilates toward sink organs, also promoted a mobilization of nonreducing sugars, which would leave a higher content of residual sugars in the wines from the defoliated plants.

Otero *et al*. (2010) found that in wines from the Albariño variety, there was no variation in residual sugars, regardless of defoliation severity. Similarly to these authors, Kemp (2010) found that partial defoliation did not induce changes in residual

sugars in Pinot Noir wine, regardless of defoliation timing (although this variable was slightly higher in plants defoliated 30 days after flowering and at the moment of veraison initiation in the second year of the study). Even so, Kemp found that residual sugar content in the wine showed significant differences between the two harvests evaluated, and was higher for the second year of the study which, according to this author, was due to the increased severity of defoliation in the second year, which left the fruit more exposed to solar radiation, thus increasing TSS of the fruit and therefore, both the percentage alcohol and the residual sugars in the wine.

Intrieri *et al*. (2008) and Lohitnavy *et al*. (2010) found that the TSS value in must increased when defoliation was performed before flowering, possibly due to an increase in photosynthesis rate, a change in photoassimilate mobilization patterns, or an increase in fruit temperature. To the contrary, Lavin and Pardo (2001) found no difference in must TSS between partially defoliated and control plants in either Chardonnay or Cabernet Sauvignon varieties, which indicated that plants suffered no limitation in photosynthetic capacity.

The sugar content in grapes at harvest time influences must TSS values, and this in turn is directly related to alcohol content of the wine, principally in the form of ethanol (McDonnell, 2011). In both Chardonnay and Cabernet Sauvignon varieties, Lavin and Pardo (2001) found no significant difference in alcohol content of wine from defoliated plants as compared to control plants. In the same way, Otero *et al*. (2010) affirmed that early partial defoliation does not affect alcohol content in wine from Albariño grapevines. Nevertheless, must TSS and wine alcohol content showed significant increases in the varieties Cynthiana, Sauvignon Blanc, and Riesling (Main and Morris, 2004; Kozina *et al*., 2008). The differences seen in the present study suggest that grape quality, and in particular TSS, at time of harvest has a marked influence on alcohol content in Chardonnay wines.

Muñoz *et al*. (2002) found that alcohol content in wines from the Cabernet Sauvignon variety showed no significant difference between partially defoliated plants and controls, but it did go down when shading was increased around grape bunches. They affirmed that the quality of light reaching grape bunches influences fruit quality, and hence alcohol percentage in the wine. Likewise, Rodriguez *et al*. (2010)

found that higher maximum temperatures favor the production of wines with high alcohol content and low acidity. In the present study, the removal of 50% of the leaf area possibly induced an increase in fruit temperature due to a higher level of radiation reaching grape clusters, which would explain the increase in potential alcohol in wines obtained from defoliated plants. An increase in average maximum temperature induces lower acid accumulation in fruit because acids are degraded (Ferrer *et al*., 2007). This is in contrast to total soluble solids, which are produced by photosynthesis in leaves; TSS biosynthesis increases when the temperature rises (Hidalgo, 2006).

Diago (2010) also found that alcohol content in wines from the varieties Tempranillo, Graciano, and Mazuelo increased when plants were subjected to early defoliation, which coincided with a higher sugar content in grapes from defoliated plants. This causality was confirmed by the author in the second year of the study, when neither must TSS nor wine alcohol content showed significant differences between defoliated and control plants for the Graciano and Mazuelo varieties.

The wine pH in the present study showed significant differences between treatments (P<0.05). The average pH of wines obtained from the defoliated plants was 4.13, while the control wines were more acid, with a pH of 3.96 (Figure 2).

Otero *et al*. (2010) reported that early defoliation has no influence on pH value in Albariño wines. In the same way, Diago (2010) affirmed that the pH in wines from Tempranillo, Graciano, and Mazuelo vines was not modified when plants underwent partial defoliation. Similar results were reported by Calderon (2004) and Muñoz *et al*. (2002), both of whom found that in Cabernet Sauvignon plants, the wine pH did not show significant differences between defoliated plants and control plants. The latter authors did however find a slightly lower value of pH in defoliated plants, which they attributed primarily to the direct relation between potassium content and pH, since in grapevines, the highest accumulation of potassium occurs at the moment of veraison, and defoliation was carried out at that moment. The timing of defoliation negatively influenced potassium accumulation in the grapes, thus inducing a lower pH value in the fruit and in the wine.

Lavin and Pardo (2001), who evaluated defoliation at different moments in plants from Chardonnay and Cabernet Sauvignon varieties, found in both cultivars
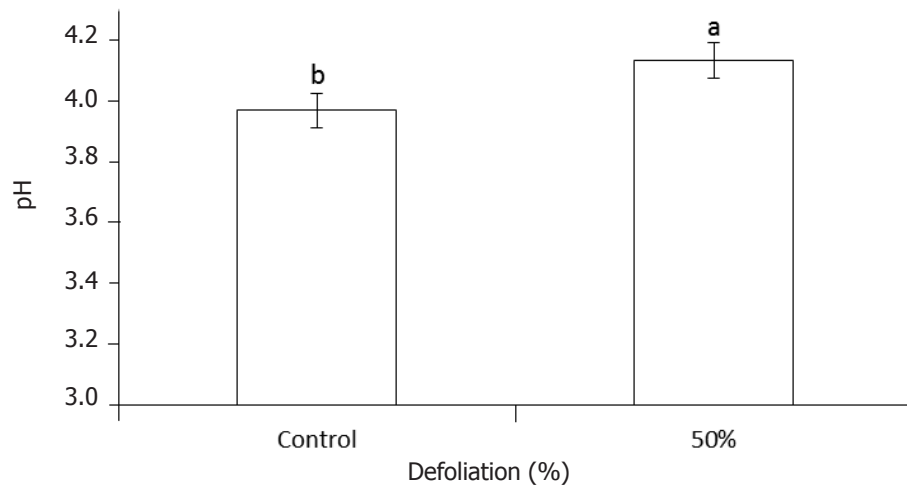
Figure 2. pH in wine produced from grapevines (*Vitis vinifera* L. cv Chardonnay) subjected to partial defoliation (n = 3).

that the wine pH was higher in non-defoliated controls. In contrast, the present study registered a higher pH in wine from the defoliated plants than in wine from the control plants. This was due to grape characteristics at the start of fermentation, given that, according to Peña-Olmos and Casierra-Posada (2012), who worked with the same plants as the present study, fruit from the defoliated plants had a higher pH and lower titratable acidity than the control plants.

In the present study, the wine total titratable acidity (TTA) showed significant differences between treatments (P<0.05). The wine from the defoliated plants possessed 23.5% lower TTA than wine from the control plants (Figure 3).
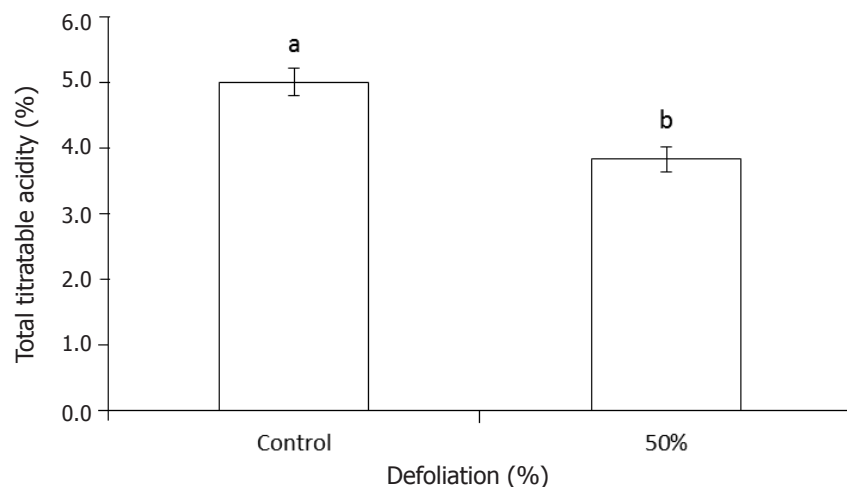

Figure 3. Total titratable acidity (TTA) in wine from *Vitis vinifera* L. cv Chardonnay plants subjected to partial defoliation (n=6).

In contrast, Otero *et al*. (2010) found that early partial defoliation did not lead to TTA variation in wines from Albariño variety grapes. By the same token, Diago (2010) reported no significant differences in TTA of wine from Tempranillo or Graciano varieties subjected to early defoliation, but they did find a difference in TTA in the Mazuelo variety between control plants and those defoliated at fruit set. Lavin and Pardo (2001),

who evaluated the effect of defoliation at different moments in plants of *Vitis vinifera* cv. Chardonnay, found no significant difference in TTA from the wine produced (although the value for the control plants was slightly lower than in the various defoliated plants). In this same study, the authors found that in Cabernet Sauvignon plants, the total titratable acidity did show significant differences, with higher values when defoliation was performed after fruit set and veraison phases, as compared to non-defoliated plants. Calderon (2004) affirmed that in Cabernet Sauvignon plants, wine TTA rises with severe defoliation at the time of veraison.

Total titratable acidity in wine or in grape must is mainly related to the accumulation of organic acids, especially tartaric and malic acids. When severe pruning is performed, the plant canopy is thinned, which induces a higher accumulation of tartaric acid as compared to plants with a denser foliage (Haeselgrove *et al.*, 2000). Despite this, Valdivia (2001) claimed that the exposure of racemes to higher radiation (as is the case with defoliated plants) increases respiration in fruit cells, which induces a higher consumption of organic acids, and for this reason TTA decreases in fruit from defoliated plants, thus leading to a directly proportional reduction in TTA of wine from this fruit.

Archer and Strauss (1989) evaluated the influence of two levels of shading on grape production and quality, must quality, and wine quality in Cabernet Sauvignon plants, and found that shade reduces fruit quality and thus wine quality. In the present study, although whole plants were not subjected to different levels of shading per se, plant architecture was modified in such a way that the canopy of the defoliated plants was less dense, and thus the fruits effectively received less shading. Wine characteristics result from grape quality at the time of harvest (Almanza *et al.*, 2011); in this way, the wine from fruit receiving more direct radiation presents higher TSS values and lower titratable acid values, which makes for better wine quality (Archer and Strauss, 1989). This is in accord with results obtained by Peña-Olmos and Casierra-Posada (2012) working on the same plants as the present study, who found higher TSS values and lower titratable acidity averages in fruit from defoliated plants.

Muñoz *et al.* (2002) found in Cabernet Sauvignon plants that defoliation does not trigger significant changes in TTA, even though the value for this variable was slightly higher in defoliated plants. In the present study, the TTA value in the wine fell drastically with defoliation, which coincides with grape characteristics at the start of fermentation. The decrease in the TTA of the wine from defoliated plants in the present study indicates a lower proportion of ionized acids, which is to say that they are bound to cations such as K^+ and Ca^{+2} (Calderon, 2004). In wine production, this is extremely important, as an increase in TTA implies a longer tartaric stabilization time once bottled (Zoecklein *et al.*, 2000).

CONCLUSION

Partial defoliation may be employed as a management practice in grape-growing that improves must quality, specifically for the Chardonnay variety and under the soil and climate conditions in which the present study was realized. It is recommended that the plants of the present study continue to be followed in order to evaluate the effect of defoliation on subsequent cropping cycles. Furthermore, it would be useful to evaluate the effect of defoliation at different moments of plant development, given that it is a labor-intensive and costly procedure that may only be required at certain key moments and not during the entire growth cycle.

ACKNOWLEDGMENTS

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